INFORMATION RECORDING MEDIUM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an optical information recording medium for recording and/or reading information optically, in particular, relates to an optical disk technique.

2. Description of Related Art

As one way to achieve a high capacity optical disk, a multilayered medium technique having a laminated information recording layer has been proposed. As a read-only disk, a dual-layered DVD-ROM is achieved. As for a rewritable dual-layered medium, Japanese Journal of Applied Physics Vol. 38, pp. 1679 to 1686 (1999) introduces such a technique therein, for example. In these techniques, a recording layer is cumulated with an interval of several 10 μm, and recording/reading information by focusing optical spots onto each layer. Information on a side further than an incident light is recorded/read as the light passes through the layer on the side of the incident light. When reading the information, the light passes the layers on the side of the incident light twice.

These techniques can increase a recording capacity of a medium of the same size about twice.

JP-A-21720-1993 discloses a triple-layered recordable medium using a high transmittance organic recording film. In this method, transmittances of three layers are 70%, 80% and 90%, respectively, and a recording mark thereof is 100%. By detecting an amount of transmitting light, data recorded on three layers are read at the same time. The method is capable to increasing a recording density and data transfer rate by about three times.

As for an optical disk using a nonlinear optical layer, a method of photon super-resolution is proposed. Several methods using this technique have been proposed, and Japanese Journal of Applied Physics Vol. 32, p. 5210 discloses one of them, for example. The method is characterized in that by providing a mask to a part of optical spot so as to transmit light only through an unmasked portion, an effective spot diameter is reduced, thus increasing density and capacity of the optical disk. Specifically, in the photon super-resolution, when the light focuses on a film, the light transmittance of the light of higher intensity is increased whereas reflectance of non-focused portion is high. In known techniques in the photon super-resolution, a medium has reflective films, and transmittance of the medium itself is always substantially 0%.

The abovementioned techniques, however, have some problems. In recordable and rewritable optical disks, in particular, it is difficult to form a dual-layered medium that secures a process margin in consideration of mass productivity and products or margins for recording/reading condition. This is because it is difficult to achieve an optimum optical design allowing for high signal modulation in both layers. To increase the signal quality obtained from the light-incident side, the transmittance of the layer should be lowered and it is better to increase reflectance and create larger differences in reflectance between a marked portion and a spaced portion. On the other hand, however, for the layer of further side, the higher the transmittance of the layer on the light incident side is, the higher signals can be received. As such, as for setting transmittance of the light incident side layer, the signal needs to be shared by two layers because the optimum transmittance for both layer contradicts. More details thereof will be described hereinbelow.

Hereinbelow, a dual-layered phase change medium will be described. Hereinbelow, L0 denotes a layer on a side of incident light, L1 denotes a layer on further side, Rc denotes disk reflectance of crystal, and Ra denotes amorphous thereof. Rc and Ra of L0 and L1 are shown respectively as Rc0, Ra0, Rc1, and Ra1. An amount of

reflected light/incident light, i.e., drive reflectance, is shown Rcd and Rad, and transmittance of L0 is shown as T0.

Suppose T0=60% and (Rcd, Rad) =(15%, 2%). The reflectance shown is values close to reflectance of a phase change disk that is currently produced. It is desirable to obtain the same amount of signal from L0 and L1. Calculation of reflectance while taking the above into consideration, a setting value for reflectance of the L1 is (Rc1,Ral)=(41.7%, 5.6%). However, it is difficult to design disk for a phase change medium capable of overwriting that has reflectance of 40% or higher. If T0 is set higher than 60%, reflectance and light absorption of the L0 is lowered significantly, and it becomes impossible to obtain desirable property at the L0. Moreover, it is necessary that the transmittance is substantially the same as crystalline state and amorphous state due to the following reason: the L0 has a marked portion and an unmarked portion, and if the light spot passes on a border of two area of the L0 as the light reads the L1, the direct current element and amplitude of the signal in reading L1 fluctuate, thereby causing an increase of jitter or error rate. Therefore, accidental error of transmittance for those two states should be suppressed less than 5 to 10%. However, maintaining translucent transmittance with the range is difficult when considering the process margin.

Moreover, even a dual-layered medium generates problems such as above, it is almost impossible to achieve a recordable/rewritable optical disk having three or more layers.

The triple-layered recordable disk technique described above detects transmittance. In this method, however, optical systems need to be placed on the top and the bottom of the disk. Such a structure makes it difficult to adjust the optical systems, thereby lowering production margin of the drive. Moreover, the method is not applicable to a rewritable disk.

In the super-resolution technique, an effective spot diameter can be smaller, thus allowing for higher density. However, the technique has drawbacks as follows: A. When considering a process margin for mass productivity, it is difficult to make a size of the light transmitting portion constant over an entire surface of the disk; B. In the optical disk, a signal noise ratio S/N becomes an issue, and an area of an effective spot as a part of the spot diameter determines the signal while a spot diameter irradiating the disk determines the noise, whereby the signal is increased for a short mark but overall S/N including the one for a long mark is lowered.

SUMMARY OF THE INVENTION

In view of the above, the transmittance of L0 should be high at least while reading the L1 in consideration of the L1. When reading the L1, a signal for reading the L1 is determined by a square of the transmittance of L0, that is T_0^2. A value of the obtained signal should be no lower than a half of the signal obtained from a single layer of L1, thus desirable as expressed in:

EXPRESSION 1

$$T_0^2 \geq 50\%$$
$$\therefore T_0 \geq 71\%$$

In the case of a triple-layered medium, the signals are determined by a square of transmittance of L0 when reading the L1, i.e., T_0^2, and a product of squared transmittance of L0 and L1, i.e., $T_0^2 T_1^2$, when reading the L2. In this case, each signal for reading L0 and L1 is desirable as expressed by:

EXPRESSION 2

$$T_0^2 \geq \frac{2}{3} = 67\%$$

$$\therefore T_0 \geq \sqrt{\frac{2}{3}} \approx 82\%$$

EXPRESSION 3

$$T_0^2 T_1^2 \geq \frac{1}{3} = 33\%$$

$$\therefore T_1 \geq \sqrt{\frac{1}{2}} = 71\%$$

When the expressions are generalized, transmittance for reading a J^{th} layer of an n-layered recording medium can be expressed as:

EXPRESSION 4,

$$\prod_{i=1}^{j-1} T_i^2 \geq \frac{n-j+1}{n}$$

where i-layer and j-layer used herein mean a laminated film interposed between a substrate and spacer layer, or a laminated film interposed between a spacer layer and another spacer layer, the i-layer or the j-layer composed of a lower protective layer, a recording layer, an upper protective layer, a nonlinear optical layer or a reflective layer.

However, as described above, it still has high transmittance, thereby making it difficult to design the L0.

Such a problem can be solved by producing a medium where the transmittance is lowered and reflectance enhanced as the light focuses thereon. Such a mechanism will be described later.

In the above-described Expression 4, transmittance of the first layer to the j-1[th] layer is dealt with all together, but it is desirable to design in such a manner that a signal is equally divided among respective layers. In the case of a triple-layered medium, for example, T0 and T1 fulfilling Expressions 2 and 3 is:

EXPRESSION 5.

$$T_0 \geq \sqrt{\frac{2}{3}}$$

$$T_1 \geq \sqrt{\frac{1}{2}}$$

By generalizing the expression, transmittance Ti of the i^{th} layer only needs to fulfill

EXPRESSION 6.

$$T_i \geq \sqrt{\frac{n-i}{n-i+1}}$$

Moreover, it is possible to design a medium that secure the process margin if the transmittance is 50% or less when the

light is focusing. In this case, signals on layers further than a light-focusing layer seeing from the light incident layers is not read, and thus, it is not necessary to consider differences in transmittance of crystal and amorphous as described above. The transmittance is low enough to make designing a medium while securing process margins easier. In the present specification, a phrase "when the light is focusing" herein is defined as a case when a light spot diameter on a film surface becomes 105% or less of a size of a minimum beam constriction of the optical system concerned. A term "spot diameter" used herein means a diameter of intensity of $1/e^2$ of the central intensity when the spot of the light approximated to the gaussian distribution. When the spot diameter spreads by 5%, the central intensity is about 90%, thereby it is considered within a margin of mechanism shown below.

A medium that changes transmittance and reflectance, as described above, can be achieved by using a substance whose optical property changes depending on an energy density of a light applied to the L0, i.e., by using a nonlinear optical layer. When the nonlinear optical layer is provided between the L0 recording film and L1 recording film, the nonlinear optical layer should be composed of a material that is transparent or translucent when the light is not focused on the L0 recording film, and has a higher

reflectance when the optical spot focuses on the L0 recording medium compared to a case where the light is not focused. Such a change occurs due to absorption of the light. That can be achieved by either using a photon mode or the heat generated by the light absorption. The change should occur by depending on the light power density applied to the substance. In order to read the L1 immediately after reading the L0, the change has to return to an original state within a certain period of time, and the transmittance of the L0 has to be high again. It is desirable that it returns to normal naturally during one disk revolution, for example. If the change occurs by heat, the temperature should return to the original during one disk revolution so as to reverse the change to the original state.

The mechanism is not only applicable to a dual-layered medium but to a multilayered medium having 2 or more layers.

FIG. 1 illustrates the mechanism. When the light of high power density does not irradiate a nonlinear optical layer 104, i.e., when there is not incident light, and when recording and reading the L1, reflectance of the nonlinear optical layer 104 is low while transmittance is high. On the other hand, when recording/reading the L0, a portion 110 irradiated with light becomes metallic, thereby increasing the reflectance.

The above-described object is achieved by providing a nonlinear optical layer between a substrate and a second recording film (L0 layer), the nonlinear optical layer has a property in which the transmittance thereof is higher than the reflectance when the light is focusing, and the reflectance is higher than the transmittance when the light is not focusing. The recording layers are not limited to two layers, and the structure is applicable to a multilayered recording medium having more than two recording layers.

The following materials may be used as a nonlinear optical layer: a) thermochromic material, b) transition metal oxide showing semiconductor-metal transition, c) garnet, and d) magnetic semiconductor.

The thermochromic material changes wavelength dependency of reflectance and transmittance reversibly by temperature. One example thereof is a material of triphernylmethane dye. A super-resolution optical disk using the aforementioned material is disclosed in Japanese Journal of Applied Physics Vol. 39, pp 752 to 755 (2000).

A semiconductor-metal transition is known to occur with temperature, pressure, and compound composition ratio as its variables. In this case, a material causing the transition by temperature thereof is selected. Such a material may include oxide of Ti, V, Cr, Mn, Fe, Co, Ni and

Cu. The heat dependency of electronic properties of these materials is described in, for example, Solid State Physics, Vol. 21, pp 1 to 113 (1968). If the material is solely used, optical property such as refractive index thereof before and after the transition does not change much in the wavelength range of visible light used in the current optical disks. A fact regarding VO2 is reported in Physical Review, Vol. 172, pp. 788 to 798 (1968). In order to solve the problem, free electrons generated in the transition metal oxide due to the transition is injected into another material A so as to change an optical response of the material A. In this case, the material that changes its optical response by the injection of electric charge may be metal or semiconductor. In particular, when the semiconductor is used, electric charge is injected into a conduction band so as to increase the number of carriers comparing to that before the transition, thereby increasing the effect thereof. In order to inject the electric charges efficiently, Fermi energy level of the material A should be smaller than Fermi energy level of the transition metal oxide indicating the transfer. Moreover, the injection of the electric charge is conducted through an interface. Thus, the larger an area of the interface is, the easier the electric charge is injected. Therefore, more electric

charges can be injected if the material A and the transition metal oxide are formed in a multilayered film structure.

Next, a case of using a magnetic material will be described. Among the magnetic materials, there is a kind that shows magnetic transition due to heat while changing the optical property simultaneously. Garnett, in particular, shows a strong tendency for this change. FIG.2 shows a temperature dependency of the transmittance of a bulk crystal of garnet having Ga doped thereinto. A wavelength of the light used herein is 400 nm. In FIG.2, the transmittance decreases drastically at around 120 °C. A Curie temperature of the material is about 120 °C, and thus, a change in transmittance occurs due to magnetic phase transition.

When a magnetic semiconductor is used, a band structure change due to magnetic property contributes a great deal to a change of an optical property. A temperature dependency of the optical property of the magnetic semiconductor is described, for example, in Semiconductors and Semimetals, Vol. 25, pp. 35 to 72 (1988). The magnetic semiconductor of this kind includes a material shown as RMnM, where R is a simple substance or mixture of Cd, Zn, Hg, and Pb, and M is O, S, Se, and Te. RMnM may be used as a simple substance, or may be mixed with other materials in some cases.

When the above-described nonlinear optical material is applied to a multilayered disk, it is designed in such a manner that the transmittance is high when no focused light is applied whereas it becomes low when the focused light is applied. In particular, when applying to a phase change disk, a phase change recording film absorbs the light, and thus, it is desirable to design the material to have an absorption factor of substantially 0 when the transmittance thereof is high. In this case, however, it is impossible for the nonlinear optical material to indicate transmittance change due to the light absorption. The problem can be solved by transferring heat from a film near the nonlinear optical layer that absorbs light if the nonlinear optical material indicates transmittance change by heat. The film for absorbing the light may be a recording film like a phase change film described above, or may be formed by laminating a film of metal or semiconductor within the disk. In order to transfer heat efficiently, a distance between the light absorbing film and the nonlinear optical material has to be shorter, and a thickness of the metal film or semiconductor therebetween needs to be from 0nm to 50nm.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram illustrating a structure of a dual-layered disk according to the present invention;

FIG. 2 is a graph showing a heat dependency of transmittance of a bulk monocrystal of garnet with GA doped therein;

FIGs. 3A to 3G illustrate production steps of a dual-layered medium;

FIG. 4 is a block diagram of an optical disk drive for recording and reading a multilayered disk according to the present invention; and

FIG. 5 is a diagram illustrating a structure of triple-layered disk according to the present invention.

DETALIED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiment 1

As a nonlinear optical layer 104 of FIG. 1, a multilayered structure of VO_2 and GaN is used. A laminated structure of L0 is polycarbonate substrate of 120 mm in diameter (100 μm) / a protective layer / a recording film InSe (5 nm/ a protective layer/ GaN (2 nm) / V02 (2 nm) / GaN (2 nm) /VO_2(2 nm). A laminated structure of L1 is a protective layer / a recording film InSe(22 nm)/ a protective layer / a reflective film (80 nm)/ 120 mm diameter polycarbonate substrate (1.1 mm). All films are formed by sputtering. A resin layer (spacer layer) of about 30 μm is arranged between L0 and L1. The polycarbonate substrate of 1.1 mm in diameter has grooves with a depth of about 40 nm and a width of 0.3

μm, with a pitch of 0.6 μm. Specifically, it has a land/groove structure.

FIGs. 3A to 3G shows a production process of the disk in sequence. As shown in FIG. 3A, a polycarbonate substrate 301 with a thickness of 1.1 mm is provided with a land/groove structure. On top of the polycarbonate substrate 301, a reflective film 302, a protective film and recording film 303 are sputtered as shown in FIG. 3B. Next, a resin 304 for a spacer layer is attached, and a stamper is pressed against the resin to cure the resin as shown in FIG. 3C, so as to form a land/groove pattern for the L0 as shown in FIG. 3D. Thereafter, as shown in FIG. 3E, a nonlinear optical layer 305 (GaN (2 nm)/ VO_2(2 nm)/ GaN(2 nm)/ VO_2 (2 nm)) , a protective film, and recording film 303 are sputtered. Herein, GaN is sputtered while mixing with 1% of N_2 into Ar atmosphere. VO_2 is sputtered by mixing 1% of O_2 into Ar atmosphere by using a V target. Lastly, as shown in FIG. 3F, resin for gluing the sheet 306 is attached, a polycarbonate sheet 307 with a thickness of 0.1 mm is glued therewith as shown in FIG.3G. The disk is completed by curing the resin 305. Refractive indices of the resins 304 and 306 and 0.1mm sheet 307 are generally the same. The difference in the refractive indices is less than 0.1.

Marks were recorded/read on this disk through an objective lens with a numerical aperture of 0.85 by the light

with wavelength of 400 nm. The recording/reading drive used herein is a conventional drive as shown in FIG 4. A semiconductor laser 401 as a light source is driven by a laser driving circuit, and emits linearly polarized laser beam. The light becomes parallel beam by a lens 402, passes though a beam splitter 403 so as to become circularly polarized light at a 1/4λ plate 404. The circularly polarized light is focused on a disk 407 by a lens 405 attached to an actuator 406. The reflective light from the disk 407 returns to the lens 405, and becomes linearly polarized light having reverse direction from the incident light at the 1/4λ plate, so as to distort the light path by the beam splitter 403. The light passes through a lens 408, divided by a knife-edge prism 409. One of the divided lights enters a two-division optical detector 410 for auto-focusing servo, and the other enters a two-division optical detector 411 for reading/tracking system. A ratio of light amount splitting of the knife-edge prism is the detector 410: the detector 411= 1:9.

A signal obtained by the optical detector 410 is taken for its subtracted signal. The subtracted signal is divided by a reading signal, and input to an electronic circuit for auto-focusing servo for dual-layered disks. The actuator 406 moves the lens 405 for auto-focusing. The signal input to the auto-focus servo circuit changes as a focusing point

of laser beam in the disk 407 moves, and when focused, it becomes 0. When the disk is dual layered, and the transmittance of the L1 is substantially 0, the light focuses on a surface of the sheet 307, the L0, and L1 because difference in the refractive indices between the resins 304, 306 and the sheet 307 are minute. When performing auto-focusing, the lens 405 moves closer to the disk to count the number of 0 cross points of the signal, it is possible to identify where the laser beam focuses on the disk 407 currently. Moreover, when the laser beam focuses on the L0, for example, and moves to the L1, the lens 405 moves to further side of the disk, and stops the move when the next 0 cross point is detected.

A sum signal of the signal obtained by the optical detector 411 is input to an RF signal system, and a subtracted signal thereof in input to a tracking servo circuit as a push/pull signal. The actuator 406 moves the lens 405 so as to conduct tracking servo.

The above-described drive uses a knife-edge method for auto-focus, and a push-pull method for a tracking. Alternatively, an astigmatic method may be used for focus, and a 3-beam differential push-pull method may be used for tracking, for example.

Before evaluating the dual-layered medium described above, a single layer disks having structure of L0 and L1

are formed, respectively for evaluation. The reflectance and transmittance of the L0 are measured by a spectrophotometer to find that the reflectance and transmittance of crystal and amorphous thereof, i.e., Rc, Ra, Tc, Ta, are (Rc0, Ra0, Tc0, Ta0) =(5%, 5.5%, 71%, 62%), correspondingly, and for the L1, (Rc1, Ra1) =(20.3% and 6.2%).

For evaluation of the dual-layered medium, the L0 is focused first. The reflectance calculated from an amount of reflecting light obtained at the drive, i.e., the drive reflectance is (Rc, Ra) =(10.7%, 3%). The result is different from the value obtained by a spectrophotometer as described above because refractive indices of VO2 and GaN have changed due to semiconductor-metal transition. A laser beam pulse irradiates the L0 to record mark of 0.194 μm long by linear velocity of 6m/s. CNR and 50dB are obtained. When random pattern is recorded by using 8-16 modulation code, jitter is 8.5% for the first recording, and 9.3% after overwriting 1000 times.

Next, the laser beam is focused on the L1. The reflectance of the L1 is (R1c, R1a) =(10.1%, 3%). The transmittance of the L0 is 71% when in crystal, is about a half of the reflectance of the L1 single layer observed by spectrophotometer, since $0.71^2 \fallingdotseq 50\%$, which agrees with the calculation. When marks are recorded in the L1 under the

same recording condition for the L0, jitter is 8.7% for the first recording, and 9.6% after overwriting 1000 times.

Embodiment 2

As a layer 104 in FIG. 1, a mixed material of triphernylmethane dye material and color development material is used. A laminated structure of L0 is polycarbonate substrate of 120mm in diameter (0.6mm)/ a protective layer / a recording film InSe(10nm)/ a protective layer (10nm)/ dye (60 nm) . A laminated structure of L1 is a protective layer / a recording film InSe(16nm)/ a protective layer / a reflective film (80nm)/ 120 mm diameter polycarbonate substrate (0.6 mm). The substrate of the medium has grooves with a depth of about 70nm and a width of 0.615 µm, with a pitch of 1.23 µm.

The production method of the medium is the same as the method described in Embodiment 1 as shown in FIGs. 3A to 3G. A dye as a nonlinear optical material is formed by vapor deposition.

Hereinbelow, the experiment is conducted with a light source having wavelength of 650nm.

The reflectance and transmittance of the produced disk measured by a spectrophotometer results in (Rc0, Ra0, Tc0, Ta0) = (0.3%, 0.3%, 91%, 77%) for the L0 single layer, and (Rc1, Ra1) = (22.2%, 3.5%) for the L1 single layer. Two

layers are combined by the resin. A thickness of the resin layer, i.e., a spacer layer, is about 50 μm.

The drive reflectance of the dual-layered medium is (Rc0, Ra0, Rc1, Ra1) = (15.6%, 4.0%, 18.4%, 2.9%). The reflectance of the L0 is different from reflectance observed by spectrophotometer because the optical property of the dye changes by focusing the light spot to the L0. From the calculation, the absorption of the dye with the above-described L structure with respect to the light with 650 nm wavelength is close to 0%. However, the optical property of the dye still changes. The reason for this is that the recording film absorbs the light and transfers the heat to the dye. In the experiment, when the thickness of the upper protective layer exceeds 50nm, a change in the optical property becomes significantly small.

Recording is made to the medium. By using an 8-16 modulation code, random mark is recorded by a shortest mark length 0.42 μm and linear velocity of 8.2m/s. At the L0, jitter was 8.2% for the first recording, and 8.6% after overwriting 1000 times, and at the L1, jitter was 7.5% for the first recording, and 8.0% after overwriting 1000 times.

Embodiment 3

As a layer 104 in FIG. 1, garnet is used. The material used herein is yttrium ion garnet (YIG) having Ga doped

therein, and a film thereof is formed by sputtering. A laminated structure of L0 is polycarbonate substrate of 120mm in diameter (90 μm)/ a protective layer / a recording film InSe(14nm)/ a protective layer / garnet(15 nm). A laminated structure of L1 is a protective layer / a recording film InSe(16nm)/ a protective layer / a reflective film (80nm)/ 120 mm diameter polycarbonate substrate (1.1 mm). The substrate of the medium has grooves with a depth of about 25nm and a width of 0.16 μm, with a pitch of 0.32 μm.

The production method of the medium is the same as the method shown in FIGs. 3A to 3G. Garnet is sputtered in 100% Ar atmosphere (except remnant gases).

Hereinbelow, the experiment is conducted with a light source having wavelength of 400 nm, and recorded on the groove.

The reflectance and transmittance of the produced disk measured by a spectrophotometer result in (Rc0, Ra0, Tc0, Ta0) = (4.1%, 10.7%, 76.3%, 59.4%) for the L0 single layer, and (Rc1, Ra1) = (34.3%, 8.9%) for the L1 single layer. A thickness of a spacer layer is about 25 μm.

The drive reflectance of the dual-layered medium is (Rc0, Ra0, Rc1, Ra1) = (16.3%, 1.3%, 16.8%, 4.4%). By using an 8-16 modulation code, a random mark is recorded by a shortest mark length 0.19 μm and linear velocity of 6m/s. At the L0, jitter is 7.8% for the first recording, and 8.4%

after overwriting 1000 times, and at the L1, jitter is 9.0% for the first recording, and 9.5% after overwriting 1000 times.

Embodiment 4

As a layer104 in FIG. 1, ZnMnTe, one of magnetic semiconductor, is used, and a triple-layered rewritable medium is formed. A laminated structure of L0 is polycarbonate substrate of 120 mm in diameter (90 µm)/ a protective layer / a recording film InSe (10 nm)/ a protective layer / ZnMnTe (10 nm) . A laminated structure of L1 is a protective layer / a recording film InSe(10 nm)/ a protective layer/ZnMnTe (10 nm). A laminated structure of L2 is a protective layer/ a reflective film (80 nm)/ 120-mm-diameter polycarbonate substrate (1.1 mm). The substrate of the medium is an In Groove substrate having grooves with a depth of about 25 nm and a width of 0.16 µm, with a pitch of 0.32 µm.

Since the medium is triple-layered, it has a structure as shown in FIG.5. The production method of the medium is the same as the method shown in FIGs. 3A to 3G, except that a method shown as FIGs.3C to 3E is added after the method in FIG. 3E. ZnMnTe is sputtered in 100% Ar atmosphere (except remnant gases).

Hereinbelow, the experiment is conducted with a light source having wavelength of 400 nm.

The reflectance and transmittance of the produced disk measured by a spectrophotometer result in (Rc0, Ra0, Tc0, Ta0) = (2.4%, 6.6%, 82.8%, 67.1%) for the L0 single layer, (Rc1, Ra1, Tc0, Ta0) = (1.4%, 3.6%, 82.8%, 67.5%) for the L1 single layer, and (Rc2, Ra2) = (23%, 1.5%) for the L2 single layer. The thickness of a spacer layer is about 20 μm.

The drive reflectance of the dual-layered medium is (Rc0, Ra0, Rc1, Ra1, Rc2, Ra2) = (10.7%, 1.8%, 10.8%, 3.2%, 10.8%, 0.7%). By using an 8-16 modulation code, random marks are recorded by a shortest mark length 0.19 μm and linear velocity of 6m/s. Jitter is 9.0% for L0, 9.5% for L1, and 8.8% for L2 for the first recording, and 10.1% for L0, 10.8% for L1, and 9.9% for L2 after overwriting 1000 times. The jitter obtained herein is a little too high for a practical used. By applying PRML (Partial Response Most Likelihood) as one of the signal process for reading, a data error rate is reduced to about 2×10^{-15}.